Verification of Translation

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of Bandai Bldg. 3rd Floor, 10-14, Kanda-Awajicho 2-chome, Chiyoda-ku, Tokyo, 101-0063 Japan, do hereby certify that I am conversant with the English and Japanese languages and am a competent translator thereof, and I further certify that to the best of my knowledge and belief the foregoing is a true and correct English translation made by me of the Japanese priority document attached hereto, No. 2000-037482.

Tokyo, Japan

This 5th day of June, 2003

Takeo Noguchi

Takeo Noguchi
Japanese Patent Attorney

PATENT OFFICE

JAPANESE GOVERNMENT

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Date of Application: February 16, 2000

Application Number: Patent Application No. 2000-037482

Applicant(s): KOMATSU LIMITED

December 8, 2000

Commissioner,

Patent Office Kozo OIKAWA

Certificate issuance No. 2000-3103411

[Document Name] PATENT APPLICATION

[Reference Number] N99125

[Directed to] Commissioner of Patent Office

[IPC] C23C 16/50

[Inventor]

[Domicile] c/o KOMATSU LIMITED, 1200 Manda, Hiratsuka-shi, Kanagawa-ken

[Name] Masayuki TAKASHIRI

[Inventor]

[Domicile] c/o KOMATSU LIMITED, 1200 Manda, Hiratsuka-shi, Kanagawa-ken

[Name] Kouichi ISHIDA

[Inventor]

[Domicile] c/o KOMATSU LIMITED, 1200 Manda, Hiratsuka-shi, Kanagawa-ken

[Name] Hiroyuki MIZUKAMI

[Inventor]

[Domicile] c/o KOMATSU LIMITED, 1200 Manda, Hiratsuka-shi, Kanagawa-ken

[Name] Toshihiro TABUCHI

[Applicant]

[ID Number] 000001236

[Name] KOMATSU LIMITED

[Agent]

[ID Number] 100091948

[Patent Attorney]

[Name] Takeo NOGUCHI

[Official Fee]

[Deposit Number] 011095

[Amount] ¥21,000

[List of Attached Document]

[Document] Specification 1

[Document] Drawings 1

[Document] Abstract 1

[General Authorization Number] 9704242

[DOCUMENT NAME] SPECIFICATION

[TITLE OF THE INVENTION] SURFACE TREATMENT APPARATUS

[SCOPE OF CLAIMS]

[Claim 1] A surface treatment apparatus for making raw material gas plasma by generating plasma, in a casing provided with plasma generation means, a raw material gas inlet and a substrate support table, by the plasma generation means and giving plasma treatment to the surface of a substrate placed on said substrate support table, characterized in that:

said casing is defined by a partition plate into two chambers, a plasma generation chamber provided with said plasma generation means and a substrate treatment chamber provided with said substrate support table;

the partition plate is provided with at least one plasma nozzle; and

the plasma nozzle forms a substantially continuous and elongated slit shape that can be drawn with a single stroke of a brush.

[Claim 2] A surface treatment apparatus according to claim 1, wherein said plasma nozzle is whorl shaped.

[Claim 3] A surface treatment apparatus according to claim 1, wherein said plasma nozzle is meandering shaped.

[Claim 4] A surface treatment apparatus according to claim 1, wherein said plasma nozzle is connected straight lines shaped.

[Claim 5] A surface treatment apparatus according to claim 1, wherein said plasma nozzle is formed symmetrically in respect with a center of the partition plate.

[Claim 6] A surface treatment apparatus according to any one of claims 1 to 3, wherein a slit width W of the plasma nozzle is set in a range satisfying either of $W \leqq 5L(e)$ or $W \leqq 20X$:

where L(e) is an electron mean free path in respect to atom or molecular species (active species) of the smallest diameter among raw material gas species and electrically neutral atom or molecular species (active species) produced therefrom by decomposition, under the desired plasma generation conditions; and

X is a thickness of a sheath layer generated under the desired plasma generation conditions.

[Claim 7] A surface treatment apparatus according to claim 1, wherein said plasma nozzle varies its slit width from a center of the partition plate to an outer circumference thereof.

[Claim 8] A surface treatment apparatus according to claim 1, wherein said partition plate varies its thickness from a center to an outer circumference thereof.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[Field of the Invention]

The present invention relates to various surface treatments to a substrate and, especially to a surface treatment apparatus appropriate for forming a film on a substrate, and more particularly to a surface treatment apparatus for forming a crystalline thin film of high quality at a high speed.

[0002]

[Prior Arts]

In a conventional parallel flat plate type plasma CVD (Chemical Vapor Deposition) apparatus, a pair of flat plate form plasma generation electrodes 23 and 24 are installed opposed in parallel in a casing 22 as in a surface treatment apparatus 21 shown in Fig. 9. Among the plasma generation electrodes 23 and 24, the upper electrode 23 consists of a hollow element, and raw material gas is introduced inside the hollow element from a raw material gas inlet 25. A plurality of raw material gas inlet pores 23a are formed at a lower wall portion of the electrode 23, so that the raw material gas is showered on a treatment area of the substrate. An upper face of a lower electrode 24 is a placing face of the substrate S, and a heater 26 for adjusting a temperature of the substrate S to a temperature suitable for vapor growth is provided at a lower portion of the lower electrode 24. If an electric power is applied between the both plasma generation electrodes 23 and 24 by a high frequency power supply P (power source of 13.56

MHz) with a substrate S placed on the lower electrode 24, plasma is generated between these electrodes 23 and 24, the raw material gas, for example monosilane gas, is activated to form a silicone film on a surface of the substrate S.

[0003]

Such conventional parallel flat plate type plasma CVD apparatus has advantage of being able to form a film on a substrate of large area by a single film forming process, by enlarging the area of the flat plate type plasma generation electrode 24 where the substrate is placed. However, in the conventional parallel flat plate type plasma CVD apparatus, the raw material gas made plasma by both the plasma generation electrodes 23 and 24 is dispersed uniformly in a film formation gas processing chamber, and only a portion thereof contributes to the film formation on the substrate disposed on the electrode. Therefore, the raw material use efficiency is low and, for example, if an amorphous silicone thin film or a fine crystalline silicone thin film is to be formed on the substrate, the film formation speed is late as about 1 to 2 Å/sec despite a high input electric power. As the consequence, it takes much more time to manufacture a semiconductor device relatively large in thickness such as a solar cell, resulting in low throughput and high costs.

[0004]

Therefore, in order to increase the film formation speed,

it is proposed to increase the input electric power by the high frequency power supply P. However, the increase of input electric power implies energy increase of charged particles in the plasma. Quality of the film formed on the surface of the substrate is deteriorated by the damage due to collision to highly energized charged particles with the substrate. Moreover, according to the increase of high frequency power by the high frequency power supply P, a quantity of fine particles are generated in the vapor phase, and the film quality will be deteriorated considerably by the fine particles.

[0005]

Consequently, in the conventional parallel flat plate type plasma CVD apparatus, the input electric power should be limited in order to avoid the film quality deterioration due to damage by high energy charged particles or fine particles. In other words, there is substantially an upper limit of input electric power, and it has been impossible to increase the film formation speed more than a certain level.

[0006]

Therefore, in the thin film formation apparatus disclosed, for example, in Japanese Patent Laid-Open Publication No. 61-32417, an activated gas generator comprising a division chamber having a pair of opposed plasma generation electrodes is disposed in a vacuum chamber for forming a thin film on the substrate. A single narrow port

is formed on one wall section of the activated gas generator for spouting out activated gas into the vacuum chamber. In addition, the substrate is supported in the vacuum chamber at a position opposed to the narrow port.

[0007]

In the thin film formation apparatus, plasma is produced by applying high frequency power to the pair of plasma generation electrodes and generating glow discharge between both electrodes. Raw material gas introduced in the activated gas generator is decomposed by this plasma. At this moment, activated raw material gas spouts out from the narrow port towards the substrate, by reducing the vacuum degree of the vacuum chamber lower than the activated gas generator by 2 to 3 places to the right through the adjustment of the vacuum pump disposed in the vacuum chamber and the conductance of the narrow port.

[0008]

Thus, the film formation speed can be increased without increasing the input electric power in the thin film formation apparatus wherein plasma generation electrodes are disposed in the activated gas generator defined in the vacuum chamber for thin film formation and raw material gas activated in the activated gas generator is actively jetted towards the substrate. Moreover, even when a stronger plasma is generated by increasing the input electric power, as the plasma

generation electrodes are disposed in the defined activated gas generator, the glow discharge between both electrodes have no chance to damage the substrate. Therefore, it is possible to increase further the film formation speed by increasing the input electric power. In addition, high quality thin film can be formed faster than before, as the thin film crystallization is accelerated, despite the film formation speed-up.

[0009]

[Problems to be Solved by the Invention]

Thus, the film formation speed has certainly been increased by dividing the plasma generation chamber and the film formation processing chamber. However, further increase of film formation speed is desired, and especially, a high speed formation of fine crystalline thin film for the application of solar cell or the like is strongly expected. Moreover, it is desired to increase the area which can be processed at one time.

In order to achieve such expectation, the present invention has an object to provide a surface treatment apparatus that can process a large area at once with high speed and high quality.

[0010]

[Means to Solve the Problem]

As mentioned above, a surface treatment apparatus with a casing defined into two chambers, i.e., a plasma generation

chamber and a substrate treatment chamber, performs higher speed and quality of surface treatment than the conventional parallel flat plate type surface treatment apparatus 21 shown in Fig. 9.

[0011]

After scrutiny for further improving the surface treatment apparatus defined into two chambers, the inventors found that the speed and quality of the surface treatment increased when a diameter of a plasma nozzle 7' formed on a partition plate 6' defining the two chambers as shown in Fig. 10 was in a certain range. The inventors suggest that its reason is that, when the diameter of the plasma nozzle 7' is in the certain range, hollow cathode glow discharge or hollow anode glow discharge is generated at the nozzle, and raw material gas plasma is enhanced, thereby increasing the number of active species.

[0012]

When a plurality of plasma nozzles 7" were formed at a partition plate 6" as shown in Fig. 11 to form a film at a large area at one time, thickness and quality of the film were not always uniform depending on plasma treatment conditions such as the intensity of the input electricity.

[0013]

Accordingly, the inventors studied further and finally obtained a surface treatment apparatus which enables formation

treatment of a film with a constant thickness and quality at any plasma treatment conditions.

[0014]

Invention according to claim 1 of the present application provides a surface treatment apparatus for making raw material gas plasma, in a casing provided with plasma generation means, a raw material gas inlet and a substrate support table, by the plasma generation means and giving plasma treatment to the surface of a substrate placed on said substrate support table, characterized in that said casing is defined by a partition plate into two chambers, a plasma generation chamber provided with said plasma generation means and a substrate treatment chamber provided with said substrate support table; the partition plate is provided with at least one plasma nozzle; and the plasma nozzle forms a substantially continuous and elongated slit shape that can be drawn with a single stroke of a brush.

[0015]

Here, a substantially continuous slit shape means, when plasma is generated by hollow discharge as mentioned below at the plasma nozzle, a slit shape that would allow this plasma to continue without dividing at one plasma nozzle. For instance, when a rib is formed traversal to the slit of the plasma nozzle, the plasma nozzle is considered substantially continuous, if dimension in a thickness direction of the

partition plate and width of the rib are sufficiently small so that plasma can override the rib and continue without being divided at the slit shaped plasma nozzle.

[0016]

As the plasma generation means, means of discharge by a pair of plasma generation electrodes consisting of a cathode and an anode, discharge having electrodes of three poles or more, microwave discharge, capacitance coupling type discharge, inductive coupling type discharge, helicon wave discharge, PIG discharge, electron beam excitation discharge or others can be adopted.

[0017]

When conducting surface treatment with the surface treatment apparatus mentioned above, raw material gas and carrier gas are injected into the casing through the gas supply channel, and plasma is generated in the plasma generation chamber by the plasma generation means. At that time, the air pressure of the substrate treatment chamber is adjusted to a lower pressure than that of the plasma generation chamber, so plasma in the plasma generation chamber flows into the substrate treatment chamber. The raw material gas and carrier gas can be injected further after the plasma flows from the plasma nozzle. The activated raw material gas in the plasma reaches the surface of the substrate in the treatment chamber with the plasma flow, thereby applying to the substrate surface

treatment such as etching and film formation.

[0018]

In the present invention, by forming the plasma nozzle as a substantially continuous and elongated slit shape that can be drawn with a single stroke of the brush, plasma is generated by hollow discharge at the plasma nozzle. This hollow discharge becomes hollow cathode glow discharge or hollow anode glow discharge depending on the potential of the plasma nozzle.

[0019]

The density of plasma induced in the substrate treatment chamber increases because plasma is newly generated at the plasma nozzle by the hollow discharge. In addition, the energy of the charged particles (electrons or ions) in the plasma is lowered because of interaction such as collision when the plasma generated in the plasma generation chamber passes the plasma nozzle where the hollow discharge is generated. As the energy of electrons are lowered, the energy becomes high enough to generate from raw material gas neutral active species contributing to surface treatment and low enough not to generate ions which may collide against and damage the surface of the substrate. Consequently, the number of neutral active species can be increased without raising the number of ions. Also, by decreasing the number of high energy ions in the plasma, damage to the substrate from the ions can be mitigated.

[0020]

The speed of surface treatment becomes higher because the plasma density increases and the number of neutral active species contributing to surface treatment raises by means of hollow discharge. Also, deterioration of the substrate surface can be suppressed by decreasing the energy of the ions existing in the plasma and colliding against and damaging the substrate. Accordingly, surface treatment can be conducted with high quality and speed.

[0021]

Further, it becomes possible to treat the surface over a large area of the substrate by a single treatment, as the plasma nozzle is elongated slit shaped, in other words, the plasma nozzle opens for an area larger than the conventional case where a single nozzle is disposed at the partition wall center.

[0022]

Glass, organic films or metal such as SUS can be used as the substrate. In addition, the surface treatment apparatus of the present invention can be used for various kinds of surface treatment such as film formation, ashing and etching. Furthermore, the surface treatment apparatus is used especially in forming silicone thin films, such as amorphous silicone and crystalline silicone, or oxidized films on the substrate surface.

[0023]

The raw material gas inlet can be open to the plasma generation chamber. Alternatively, only carrier gas can be introduced into the plasma generation chamber and the raw material gas inlet can be open to a side surface of the plasma nozzle. Further, the raw material gas inlet can be open to the substrate treatment chamber by using such introducing means as a pipe for inducing the raw material gas, and the raw material gas can be introduced between the plasma nozzle in the substrate treatment chamber and the substrate. When the raw material gas inlet is made open to the nozzle or to the substrate treatment chamber, the raw material gas becomes plasma by the plasma carrier gas passing the nozzle. In this case, the inner wall face of the plasma generation chamber is not stained by the raw material gas.

[0024]

When a pair of plasma generation electrodes are used as the plasma generation means, DC or high frequency power can be applied to the electrodes by connecting a DC power supply or high frequency power supply. Yet, it is preferable to input high frequency power. Moreover, bias can be applied to each electrode by means of a DC or AC power supply.

[0025]

Preferably, the plasma nozzle is, as in the invention according to claims 2-4 of the present application, whorl

shaped, meandering shaped, connected straight line shaped or the like.

Further, according to the invention of claim 5 of the present application, the plasma nozzle is formed symmetrically in respect with its center, by which the substrate surface can be treated more evenly.

[0026]

Further, in order to generate hollow discharge more effectively at the plasma nozzle and, at the same time, to spout out plasma effectively from the plasma nozzle, preferably, the slit width W of the plasma nozzle is set in a range satisfying either of $W \leqq 5L(e)$ or $W \leqq 20X$. L(e) is an electron mean free path in respect to atom or molecular species (active species) of the smallest diameter among raw material gas species and electrically neutral atom or molecular species (active species) produced there from by decomposition, under the desired plasma generation conditions and X is a thickness of a sheath layer generated under the desired plasma generation conditions.

[0027]

Meanwhile, the electron beam free path in the dispersion of the electrons and gas molecules (including atoms) depend on gas pressure, an area of dispersion cross section of the atoms or molecules, and temperature. Said plasma generation condition includes these gas pressure, area of dispersion cross

section of the atoms and molecules, and temperature.

[0028]

In the invention according to claim 7 of the present application, the plasma nozzle varies its slit width from the center to the outer circumference of the partition plate.

Also, in the invention according to claim 8 of the present invention, the partition varies its width from the center to the outer circumference thereof.

[0029]

In the aforementioned surface treatment apparatus, when a pair of plasma generation electrodes is adopted as plasma generation means, the plasma density of hollow discharge generated at the plasma nozzle may vary by the high frequency power applied to the electrodes according to the distance from the nozzle center. In such a case, it can be controlled so that plasma is generated with an uniform density over the total length of the plasma nozzle, for example, by changing the dimension of the slit width or the partition plate thickness, from the center to the periphery of the partition plate, so that the slit width reduces or the partition plate thickness increases at a portion where hollow discharge occurs easily, or on the contrary, the slit width increases or the partition plate thickness decreases where hollow discharge occurs hardly. This allows to treat all over the substrate surface uniformly.

[0030]

[Embodiments of the Invention]

Now, the embodiment of the present invention will be described concretely referring to drawings and preferred embodiments.

Note that an electrode to apply main power for discharge is a cathode electrode and an electrode opposing to the cathode electrode is an anode electrode in the following description.

[0031]

Fig. 1 is a schematic view of a surface treatment apparatus 1 according to a first embodiment of the present invention. The apparatus 1 is shielded from the atmosphere, and a grounded casing 2 is divided into two chambers, a plasma generation chamber 3 and a substrate treatment chamber 4.

[0032]

A pair of plasma generation electrodes 5 and 6 are disposed in parallel vertically in the plasma generation chamber 3. The upper electrode (cathode electrode) 5 connected to a high frequency power supply P of the pair of electrodes 5 and 6, is attached to an upper wall 2a of the casing 2 through an insulator 2, while the grounded lower electrode (anode electrode) 6 defines the plasma generation chamber 3 and the substrate treatment chamber 4. Here, the anode electrode 6 is attached to a peripheral wall 2b of the grounded casing 2, it is not limited to this, but it can be attached to any position of the casing 2.

[0033]

The cathode electrode 5 has a hollow cylindrical shape, a gas inlet 8 is formed at the upper wall section 5a of the cathode electrode 5, and mixed gas of raw material gas such as monosilane and carrier gas to accelerate the plasma generation, stabilize the plasma and transport raw material gas to the substrate S, is introduced into the hollow inside of the cathode electrode 5 from this gas inlet 8 in case of film formation. A plurality of gas inlet holes 5c are formed at the upper wall section 5b of the cathode electrode 5, which is a section opposing to the anode electrode 6, so as to supply the plasma generation chamber with raw material gas induced in the hollow inside. Thus, the mixed gas can be introduced in the plasma generation chamber 3 with an uniform density and pressure, by retaining once the mixed gas in the hollow inside of the cathode electrode 5 and then introducing into the plasma generation chamber 3 in shower form through the gas inlet holes 5c.

[0034]

Only carrier gas may introduced into the cathode electrode 5 hollow inside, and raw material gas may be introduced inside the plasma generation chamber 3 or inside the film formation treatment chamber 4 through a different inlet installed separately.

[0035]

A slit shaped plasma nozzle 7 having a whorl shaped top surface as shown in Fig. 2 is formed at the center of the anode electrode 6, and the plasma generation chamber 3 and the substrate treatment chamber 4 are connected each other through this plasma nozzle 7. Here, separately from the anode electrode 6, a partition plate to define the plasma generation chamber 3 and substrate treatment chamber 4 can be disposed and a plasma nozzle can be formed on the partition plate.

[0036]

In this embodiment, it is important that the plasma nozzle 7 is whorl shaped, namely, formed in an elongated substantially continuous slit shape that can be drawn with a single stroke of the brush. Moreover, the slit width W of this plasma nozzle 52 is longitudinally uniform, and the whorl interval L is made equal to the slit width W. Preferably, the slit width W is set in a range satisfying either of $W \leqq 5L(e)$ or $W \leqq 20X$, and it is more preferable to set in a range satisfying $X/5 \leqq W$. L(e) is an electron mean free path in respect to atom or molecular species (active species) of the smallest diameter among raw material gas species and electrically neutral atom or molecular species (active species) produced therefrom by decomposition, under the desired plasma generation conditions, and X is a thickness of a sheath layer generated under the desired plasma generation conditions.

[0037]

A substrate support 9 is provided in the substrate treatment chamber 4 at a position opposing to the plasma nozzle 7. Since the substrate support 9 is grounded in this embodiment, the substrate placed on the support 9 is also grounded. Meanwhile, it is also possible to apply bias in a DC or AC manner without grounding the substrate support 9 or to apply bias in a pulse manner. In addition, a heater is installed in the substrate support table 9 and adjusts the temperature of the substrate S placed on an upper face of the substrate support table 9 to a temperature suitable for vapor growth.

Meanwhile, the pressure inside the substrate treatment chamber 4 is adjusted to be lower than that in the plasma generation chamber 3 by a pressure regulation valve and a vacuum pump.

[0038]

When film formation is conducted with the surface treatment apparatus 1 above, plasma is generated between the electrodes 5 and 6, i.e. in the plasma generation chamber 3, if raw material gas and carrier gas are injected to the casing through the gas inlet and high frequency power is inputted into the cathode electrode 5 by the high frequency power supply P. This plasma includes active species and ions generated from the raw material gas and the carrier gas. The plasma in the

plasma generation chamber 3 flows into the substrate treatment chamber 4 through the plasma nozzle 7 because the pressure in the substrate treatment chamber 4 is adjusted to be lower than that in the plasma generation chamber 3. The active species and ions reach the surface of the substrate S in the treatment chamber 4 by means of the flowing plasma thereby forming a thin film on the surface of the substrate S.

[0039]

Further, in this embodiment, hollow anode glow discharge is induced in the whorl shaped plasma nozzle 7. As for plasma induction in the whorl shaped formed in an elongated substantially continuous slit shape that can be drawn with a single stroke of the brush, it is believed that hollow anode glow discharge is induced at an arbitrary position inside the plasma nozzle 7, and hollow anode glow discharge is propagated in the whole inside of the plasma nozzle 7 by chain reaction.

[0040]

The density of plasma introduced in the substrate treatment chamber 4 is increased, because hollow anode glow discharge is induced in the plasma nozzle 7. Moreover, in this embodiment, the plasma nozzle 7 is formed substantially over a wide range of the anode electrode 6, by shaping the plasma nozzle 7 in a whorl form, and further, substantially uniform surface treatment can be realized over a wide range of the substrate S, because plasma is spouted out from the total length

of the plasma nozzle 7.

[0041]

In this embodiment, the generation of hollow anode glow discharge at the plasma nozzle 7 is further accelerated, because the plasma nozzle 7 slit width W is set in a range satisfying either of $W/5 \leqq 5L(e)$ or $W/5 \leqq 20X$.

[0042]

Moreover, because the electron energy in the plasma generated in the plasma generation chamber 3 is reduced conveniently to an intensity sufficient for generating active species and insufficient for generating ions when it passes through the plasma nozzle 7 which is the hollow anode discharge generation area, plasma introduced into the substrate treatment chamber 4 further increases in species contributing to the film formation, increases in its density, so as to increase the film formation speed remarkably. Still further, as the ion energy in the plasma also drops when it passes through the plasma nozzle 7 where the hollow anode glow discharge is being generated, the plasma introduced into the substrate treatment chamber 4 contains less ions damaging the substrate by collision therewith, so as to enable a high quality film formation.

[0043]

Now the effect of this invention will be described with a concrete embodiment.

[Embodiment 1]

In the surface treatment apparatus 1 according to the embodiment above, when the silicone thin film formation treatment was realized with anode electrode 6 of thickness 7.0 mm, slit width W 8.0 mm of the whorl shaped plasma nozzle 7 formed on the anode electrode 6, and whorl interval L 8.0 mm, the obtained silicone film was crystallized even when the film treatment speed was increased. The slit width used for the film formation treatment satisfies the hollow discharge induction conditions.

[Comparative example]

When the silicone thin film formation treatment was performed similarly to the Embodiment 1 using an anode electrode 6' of 7.0 mm in thickness, wherein a circular plasma nozzle 7' of 50 mm in diameter as shown in Fig. 10 is formed at the center, in place of the anode 6 of the surface treatment apparatus 1, the obtained silicone film was amorphous when the film treatment speed was increased, and crystalline silicone film could not be obtained. The orifice diameter used for this film formation treatment does not satisfy the hollow discharge induction conditions.

[0044]

[Table 1]

	Embodiment 1	Comparative example
Plasma nozzle shape	Whorl slit shape Slit width W: 8.0 mm Whorl interval L: 8.0	Circular Diameter: 5.0 mm

	mm	
Anode electrode thickness	7.0 mm	7.0 mm
Slit width conditions W ≦ (e) or W ≦ 20X	Satisfied	Not satisfied
Film formation speed	6.0 Å/sec	5.0 Å/sec
Film nature	Crystalline	Amorphous

[0045]

Though, in the aforementioned seventeenth embodiment, the anode electrode 6 is grounded, however bias may be applied respectively on the electrodes 5 and 6 by a DC or AC power supply, or by a pulse power supply. Though the plasma generation chamber 3 and the substrate treatment chamber 4 are defined by the anode electrode 6 in the embodiment mentioned above, a partition plate to define the plasma generation chamber 3 and substrate treatment chamber 4 can be disposed, separately from the anode electrode 6.

When ashing, etching or other surface treatment are performed using the aforementioned surface treatment apparatus, the surface treatment can be performed at a temperature lower and speed higher than before.

[0046]

Now, a preferred modification of the plasma nozzle which is a characteristic portion of the present invention will be described.

Similarly to the aforementioned plasma nozzle 7, a plasma nozzle 11 shown in Figs. 3 also has an whorl shaped top

face, ribs 11a for connecting the slit width at a plurality of points are formed. The form of the plasma nozzle 11 can be held stably by forming the rib 11a at a plurality of points, even when the partition plate (anode electrode 6) wherein, for example, the plasma nozzle 11 is formed, is thin. For the formation of such rib 11a, it is important that the plasma nozzle 11 is substantially continuous. Namely, it is important not to divide plasma generated in the plasma nozzle 11, by reducing the thickness direction dimensions of the rib 11a to be smaller than the plate thickness, or reducing the width dimension of the rib 11a.

[0047]

A plasma nozzle 12 shown in Fig. 4 has a zigzag meandering shaped top surface. This plasma nozzle 12 is point symmetric in respect to the center of the partition plate (anode electrode 6).

[0048]

Plasma nozzles 13 and 13 shown in Fig. 5 have also a zigzag meandering shaped top surface. This is the shape of the plasma nozzle 12 shown in the aforementioned Fig. 4 and is divided at the central portion of the partition plate (anode electrode 6). The two plasma nozzles 13 and 13 are formed point symmetrically in respect to the center of the partition plate (anode electrode 6).

[0049]

A plasma nozzle 14 shown in Fig. 6 has a substantially U-formed top surface connecting straight lines. Moreover, the open end section can be connected for rectangular shape, and liked with a rib mentioned above, so that the central portion may not drop.

[0050]

A plasma nozzle 15 shown in Fig. 7 has a zigzag meandering shaped top surface, and further, its slit width W is reduced gradually from a slit width W1 in the vicinity of the center of the partition plate (anode nozzle 6) towards the outer periphery slit width W2. In this modification, for example, when plasma is generated by applying high frequency power supply whose frequency is 13.56 MHz, if the slit width W of the whorl shaped plasma nozzle 7 is made constant, as in the surface treatment apparatus 1 shown in the aforementioned Figs. 1 and 2, plasma attaining the substrate S tends to be weak at the central portion, and becomes stronger towards an outer circumferential portion. When the plasma density is uneven as in this case, the density of plasma eventually attaining the substrate S surface can be uniformed by gradually reducing the slit width W from the vicinity of the center of the partition plate toward the outer circumference as shown in Fig. 7, and a stable film thickness distribution and film quality can be obtained at a high film formation speed.

[Embodiment 2]

The plasma nozzle 15 shown in Fig. 7 is adopted for silicone thin film formation treatment as in Example 1, be setting the slit width W1 in the vicinity of the center of the partition plate to 8.0 mm, the slit width W2 in the vicinity of the outer circumference to 6.0 mm, and the whorl interval D to 8.0 mm. As a result, crystalline silicone thin film was obtained, and its film thickness distribution was more uniformed than Embodiment 1.

[0051]

[Table 2]

	Embodiment 1	Embodiment 2
Plasma nozzle shape	Whorl slit shape Slit width W: Constant 8.0 mm Whorl interval L: 8.0 mm	Whorl slit shape Slit width W: Variable W1 8.0 mm W2 6.0 mm Whorl interval L: 8.0 mm
Anode electrode thickness	7.0 mm	7.0 mm
Film thickness distribution (uniformity)*	0.75	1.00
Film nature	Crystalline	Crystalline

* The film thickness distribution is normalized by dividing the thinnest portion of the formed film by the thickest portion.

[0052]

A plasma nozzle 16 shown in Fig. 8 has a whorl shaped top surface and a constant slit width W, further, its slit depth D, namely partition plate (anode nozzle 6) thickness dimension increases gradually from the center towards the outer periphery. As the plasma nozzle 16 shown in Fig. 8, the density of plasma

eventually attaining the substrate S surface can be uniformed by gradually increasing the slit depth D from the vicinity of the center of the partition plate toward the outer circumference, and a stable film thickness distribution and film quality can be obtained at a high film formation speed.

[0053]

As for the plasma nozzle 15 shown in the aforementioned Fig. 7, its slit width W is reduced gradually from the center of the anode electrode 6 where the plasma nozzle 15 is formed towards the outer periphery, while the slit depth D of plasma nozzle 15 shown in Fig. 8 increases gradually from the center towards the outer periphery slit width W2. This is a measure against an tendency that, when plasma is generated by applying high frequency power supply whose frequency is 13.56 MHz as mentioned above, plasma density attaining the substrate S tends to be weak at the central portion, and becomes stronger towards the outer circumferential portion.

[0054]

However, when the frequency is multiplied nearly by 8, for example about 100 MHz, contrary to the aforementioned tendency, it is observed that the plasma density tends to decreases from the center to the outer periphery. In such a case, it is preferable to increase the plasma nozzle slit width W from the center toward the outer periphery, or to reduce the slit depth D from the center toward the outer periphery.

Anyway, the slit width and slit depth of the plasma nozzle is to be set conveniently in view of the plasma density attaining the substrate S according to various plasma generation conditions such as applied power frequency, chamber pressure, temperature or others.

[Brief Description of Drawings]

[Fig. 1]

A sectional view schematically showing a surface treatment apparatus according to a preferable embodiment of the present invention.

[Fig. 2]

A plan view of an anode electrode in the apparatus.

[Fig. 3]

Plan views of an anode electrode according to another embodiment of the present invention.

[Fig. 4]

A plan view of an anode electrode according to still another embodiment of the present invention.

[Fig. 5]

A plan view of an anode electrode according to still another embodiment of the present invention.

[Fig. 6]

A plan view of an anode electrode according to still another embodiment of the present invention.

[Fig. 7]

A plan view of an anode electrode according to still another embodiment of the present invention.

[Fig. 8]

Plan and sectional views of an anode electrode according to still another embodiment of the present invention.

[Fig. 9]

A sectional view schematically showing a conventional parallel-plane-shaped surface treatment apparatus.

[Fig. 10]

A plan view of a conventional anode electrode.

[Fig. 11]

A plan view of another conventional anode electrode.

[Reference Numerals]

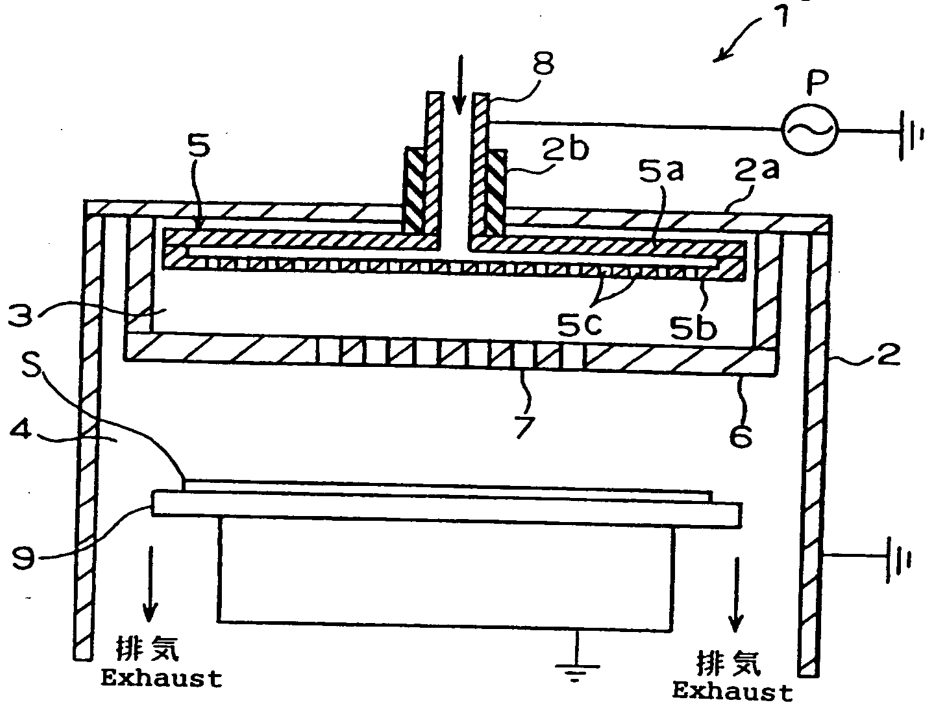
1	Surface treatment apparatus
2	Casing
2a	Upper wall
2b	Insulator
3	Plasma generation chamber
4	Substrate treatment chamber
5	Cathode electrode
5a	Upper wall section
5b	Lower wall section
5c	Gas inlet hole
6, 6′, 6″	Anode electrode
7, 7′, 7″	Plasma nozzle

8	Gas inlet
9	Substrate support table
11, 12, 13, 14, 15, 16	Plasma nozzle
21	Substrate treatment apparatus
22	Casing
23, 24	Plasma generation electrode
25	Raw material gas inlet
26	Heater
S	Substrate
P	High frequency power supply

【書類名】　図面　[DOCUMENT NAME] DRAWINGS

【図１】

本発明の好適な実施形態である表面処理装置の概略を示す断面図
[Fig. 1] A sectional view schematically showing a surface treatment apparatus according to a preferable embodiment of the present invention.

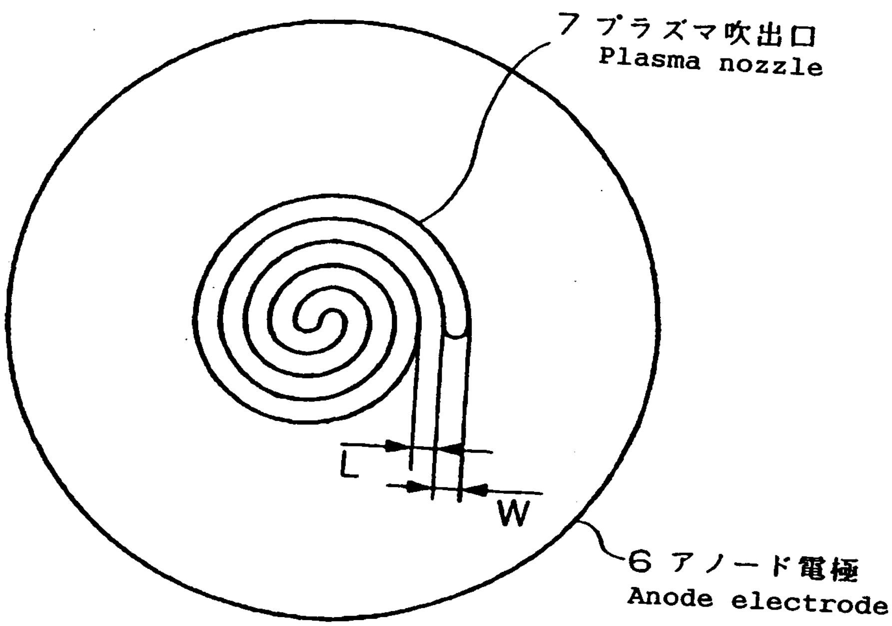


1	表面処理装置	1	Surface treatment apparatus
2	ケーシング	2	Casing
2 a	上壁	2a	Upper wall
2 b	絶縁体	2b	Insulator
3	プラズマ発生室	3	Plasma generation chamber
4	基板処理室	4	Substrate treatment chamber
5	カソード電極	5	Cathode electrode
5 a	上壁部	5a	Upper wall section
5 b	下壁部	5b	Lower wall section
5 c	ガス供給孔	5c	Gas inlet hole
6	アノード電極	6	Anode electrode
7	プラズマ吹出口	7	Plasma nozzle
8	ガス供給管	8	Gas inlet
9	基板支持台	9	Substrate support table
S	基板	S	Substrate
P	高周波電源	P	High frequency power supply

【図２】

[Fig. 2] A plan view of an anode electrode in the apparatus.

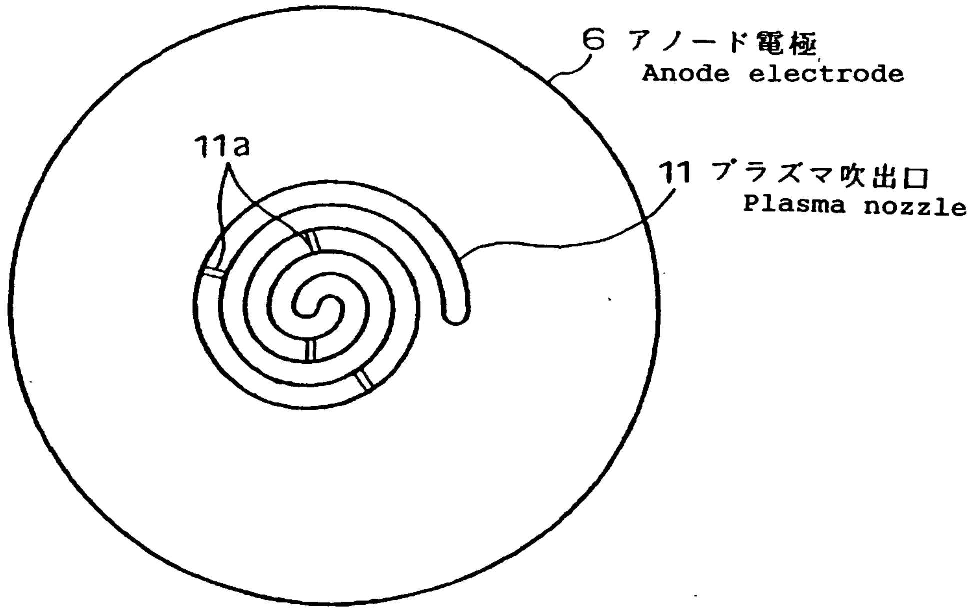
表面処理装置におけるアノード電極の平面図



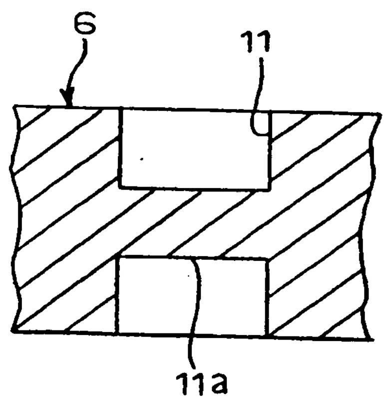
【図3】

本発明の他の実施形態によるアノード電極の平面図
[Fig. 3] Plan views of an anode electrode according to another embodiment of the present invention.

(a)



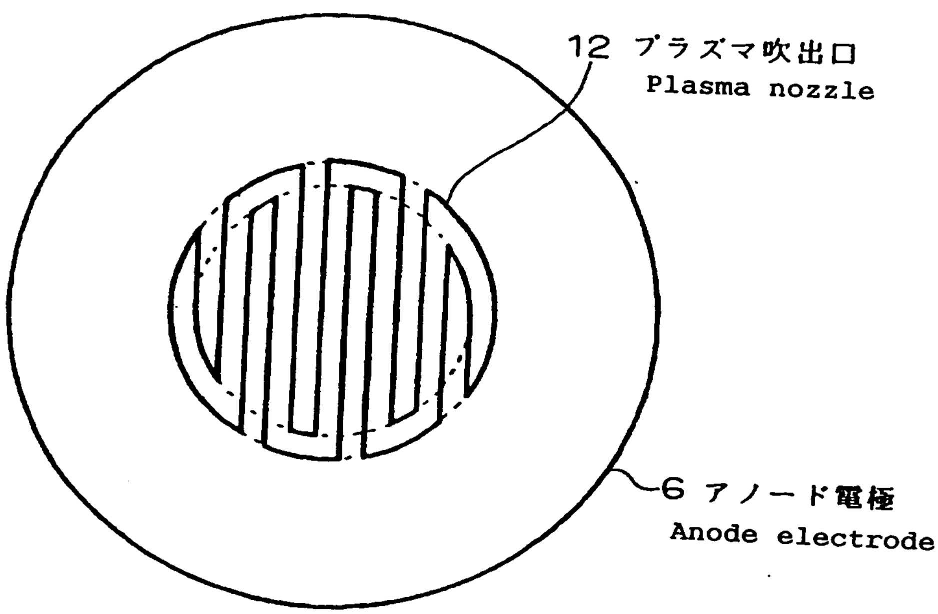
(b)



【図４】

[Fig. 4] A plan view of an anode electrode according to still another embodiment of the present invention.

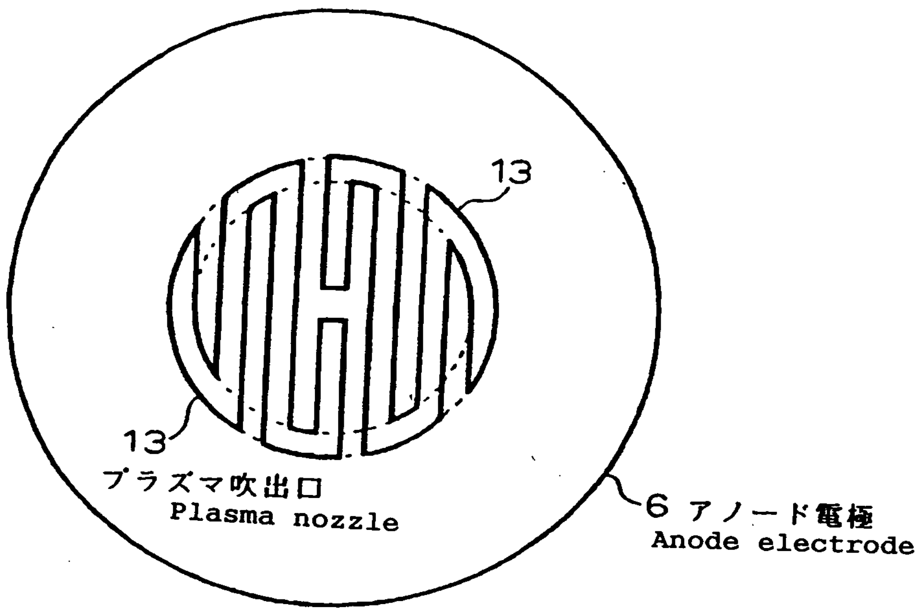
本発明の更に他の実施形態によるアノード電極の平面図



【図5】

[Fig. 5] A plan view of an anode electrode according to still another embodiment of the present invention.

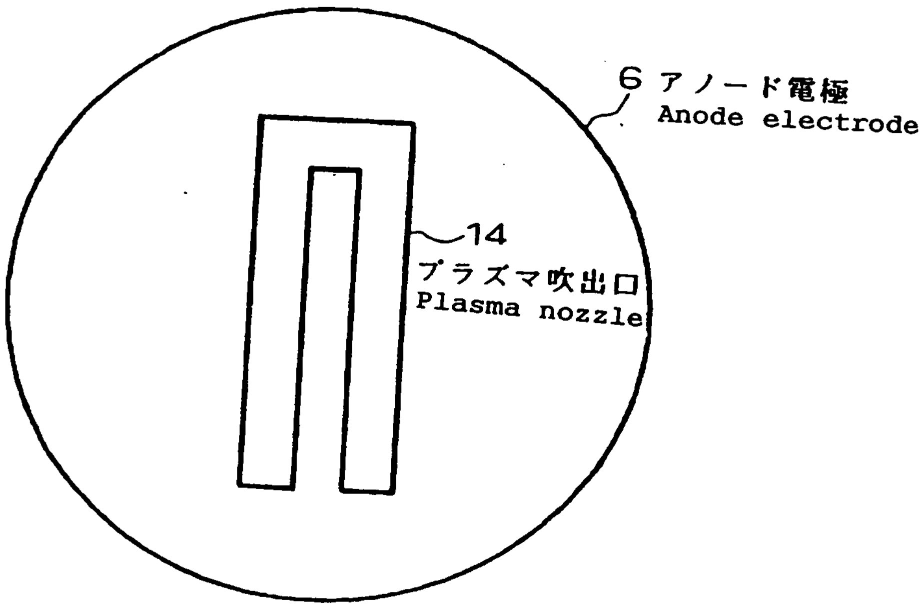
本発明の更に他の実施形態によるアノード電極の平面図



【図６】

[Fig. 6] A plan view of an anode electrode according to still another embodiment of the present invention.

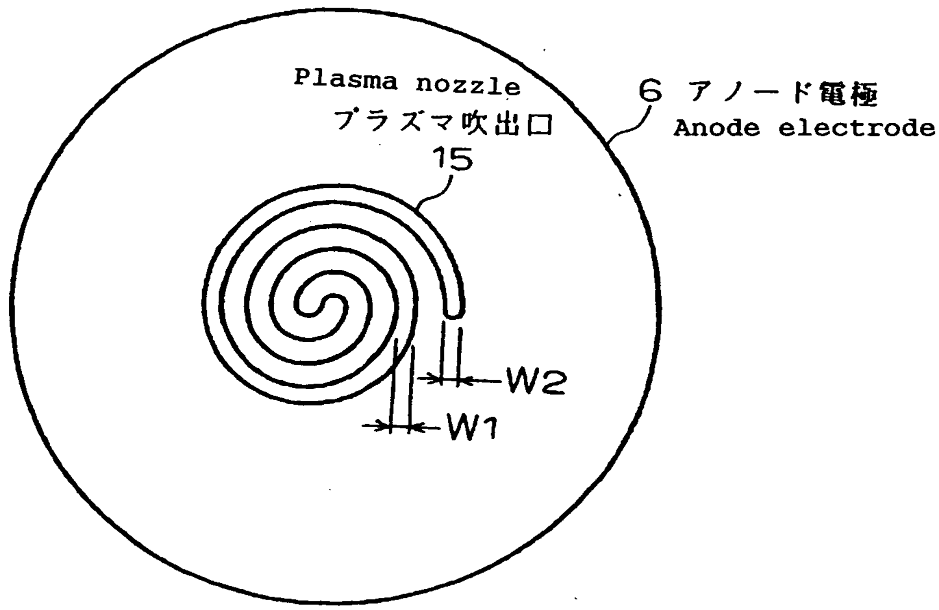
本発明の更に他の実施形態によるアノード電極の平面図



【図７】

[Fig. 7] A plan view of an anode electrode according to still another embodiment of the present invention.

本発明の更に他の実施形態によるアノード電極の平面図

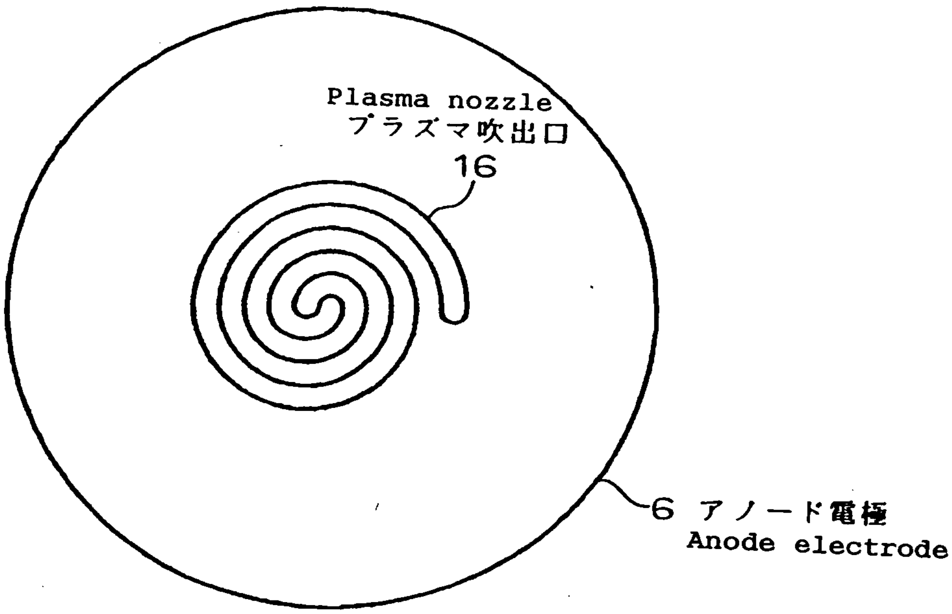


【図８】

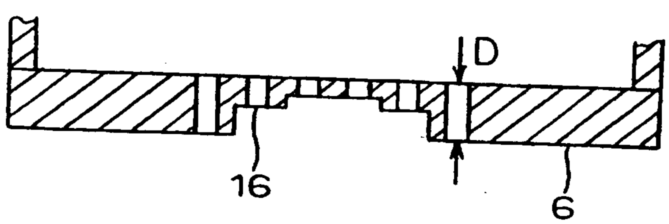
[Fig. 8] A plan view of an anode electrode according to still another embodiment of the present invention.

本発明の更に他の実施形態によるアノード電極の平面図及び断面図

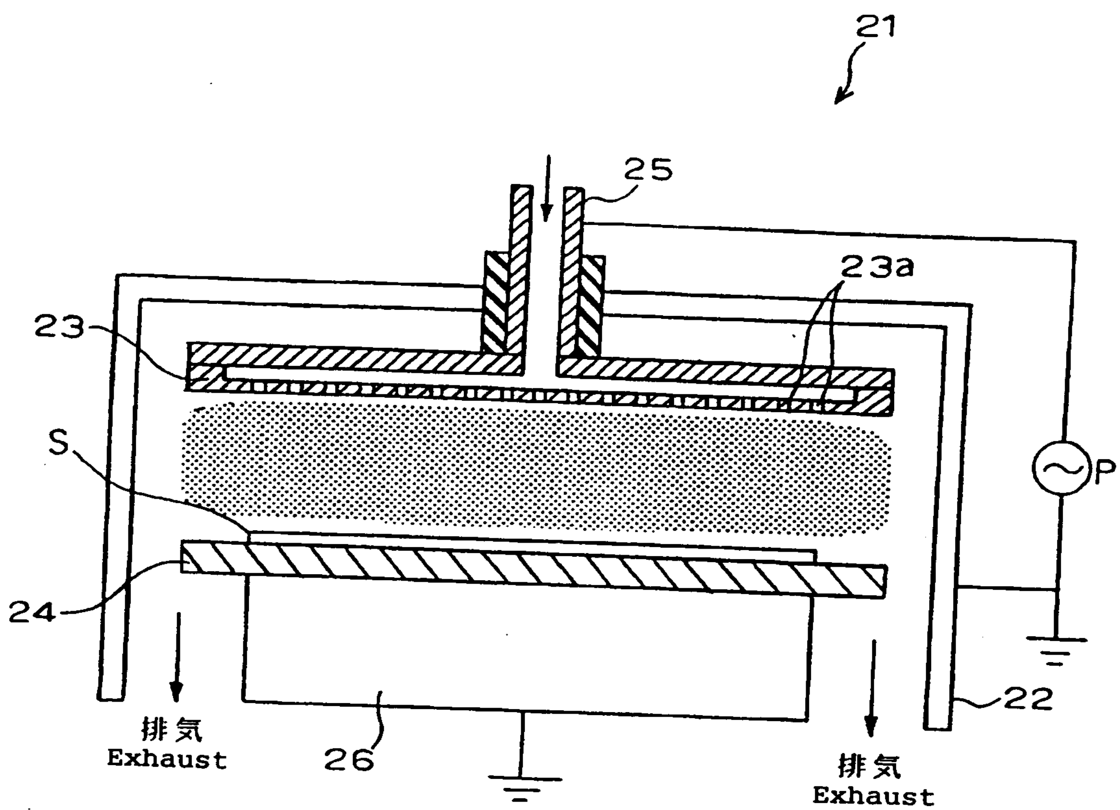
(a)



(b)



【図9】
[Fig. 9] A sectional view schematically showing a conventional parallel-plane-shaped surface treatment apparatus.
従来の平行平板型の表面処理装置の概略を示す断面図



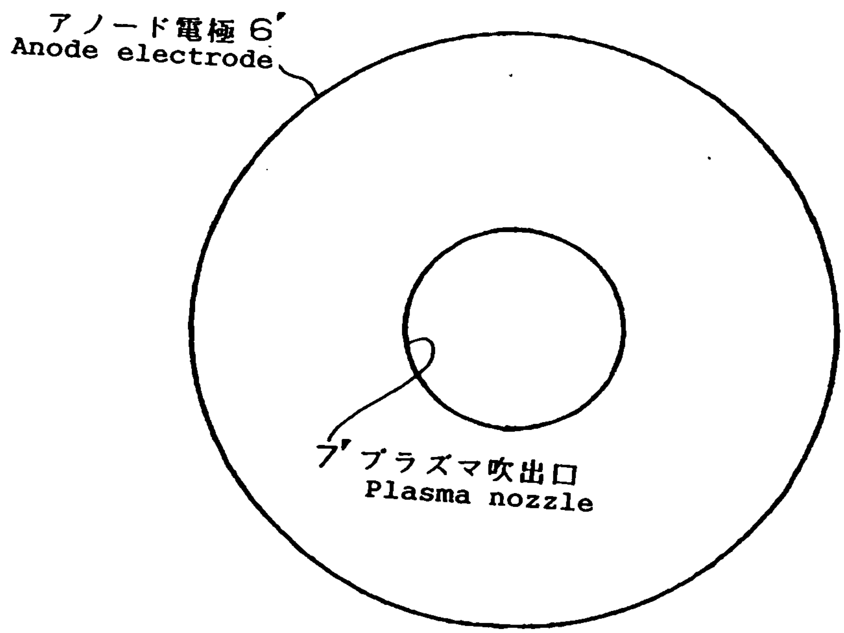
21	表面処理装置
22	ケーシング
23，24	プラズマ発生電極
25	原料ガス導入管
26	ヒーター
S	基板
P	高周波電源

21	Substrate treatment apparatus
22	Casing
23, 24	Plasma generation electrode
25	Raw material gas inlet
26	Heater
S	Substrate
P	High frequency power supply

【図１０】

[Fig. 10] A plan view of a conventional anode electrode.

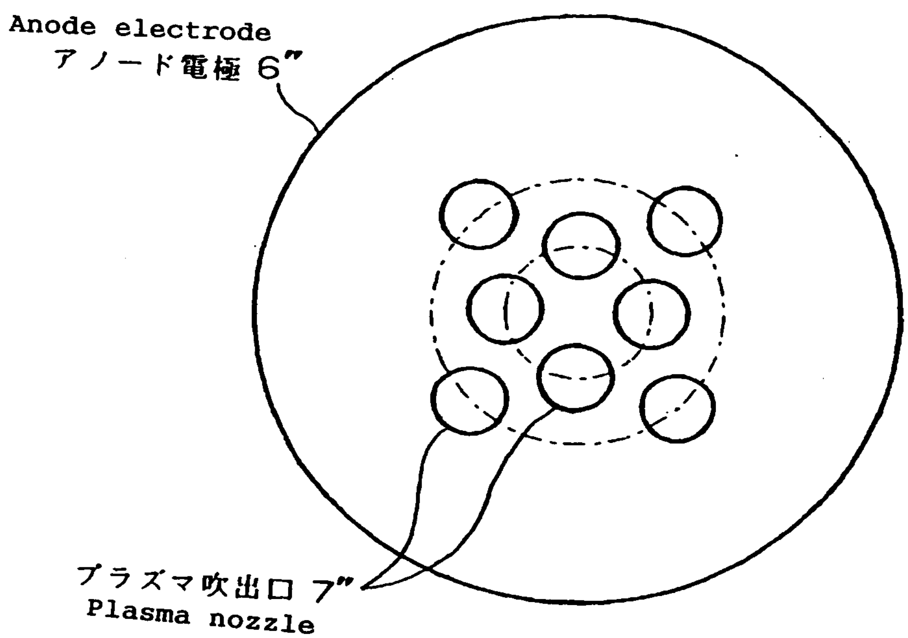
従来のアノード電極の平面図



【図１１】

[Fig. 11] A plan view of another conventional anode electrode.

従来の他のアノード電極の平面図



[DOCUMENT NAME] ABSTRACT

[Abstract]

[Object]

To provide a surface treatment apparatus which can treat a wide area of a surface with high speed and high quality.

[How to solve the problem]

A casing (2) of a surface treatment apparatus (1) is defined into two chambers, a plasma generation chamber (3) provided with a plasma generation electrode (5, 6) and a substrate treatment chamber (4) provided with a substrate support table (9). A plasma nozzle (7) is formed on an anode electrode (6) constituting a partition wall of the both chambers (3, 4). An upper face of the plasma nozzle (7) is formed in an elongated substantially continuous slit shape that can be drawn with a single stroke of the brush, such as a whorl shape.

[Selected figure] Fig. 1